STATIC ANALYSIS OF A BICYCLE FRAME USING SOLID WORKS AND ANSYS SOFTWARE

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Abstract : A bicycle frame is the main component of a bicycle, onto which wheels and other components are fitted. Strength has been gaining importance in the design of bicycle frame. Presently steel or aluminum alloy are used in cycles For the purpose of reducing weight Kevlar, glass fiber and carbon& epoxy composite materials are used to make the bicycle frames in this project Aluminum Alloy 6061T6,S glass Epoxy (composite) and HT Graphite Epoxy (composite) perform the analysis such as FEM ,structural , static analysis report the deformation under different loading conditions, And ensure the implementation of modified mountain bike frame designed in Solid works and the analysis of the bicycle frame is done by using ANSYS software tool.

Index Terms - Analysis, ANSYS, mountain bike frame, Solid works.

I. INTRODUCTION

The motorcycle chassis consists of the frame, suspension, wheels and brakes. Each of these components is described briefly below. Frame Motorcycles have a frame made of steel, aluminum or an alloy. The frame consists mostly of hollow tubes and serves as a skeleton on which components like the gearbox and engine are mounted. The frame also serves as a support for the suspension system, a collection of springs and shock absorbers that helps keep the wheels in contact with the road and cushions the rider from bumps and jolts. Wheels Motorcycle wheels are generally aluminum or steel rims with spokes, although some models introduced since the 1970s offer cast wheels. Cast wheels allow the bikes to use tubeless tires, which, unlike traditional pneumatic tires, don't have an inner tube to hold the compressed air. The front and rear wheels on a motorcycle each have a brake. The rider activates the front brake with ahand lever on the right grip, the rear brake with the right foot pedal. Drum brakes were common until the 1970s, but most motorcycles today rely on the superior performance of disc brake.

1.Two suspension can be implemented in a variety of ways…

2. Front suspension

3.Two wheeler suspension is the system, or systems, used to suspend the rider and bicycle in order to insulate them from the roughness of the terrain.

4.Rear suspension

5.Suspension seat post

6.Suspension saddle

7.Suspension stem (now uncommon)

8.Suspension hub.

Figure Bi Cycle Frame

II. LITERATURE SURVEY

Mr. M.V. Pazare and Prof .S.D. Khamankar conducted a stress analysis of bicycle frame by using Finite Element Method. The analysis is carried out in Ansys, The F.E.A. results are compared with theoretical results. They have chosen the material of the frame as Aluminum T 6061. They concluded that the stresses produced by theoretically and by Finite Element method are identical. The stresses produced from Static start up, Horizontal impact, Vertical impact, and Rear wheel braking are compared. Both theoretical and Finite element results are less than yield strength in tension i.e.(Syt = 290 MPa) for the material selected.

Sagar Pardeshi, Pankaj Desle published a IJIRSET journal on Design and Development of Effective Low Weight Racing Bicycle Frame, in this they studied about the dependency of the performance is directly proportionate to weight of the cycle and frame structural design, Optimization of weight and structure of the frame is the best scope of optimizing the overall performance of the racing cycle, A monologue design is advisable in racing utility hence we are targeting towards composite design and how its frame can be optimizes by using static and dynamic FEA Analysis using the knowledge from literature review, we can know how the CAD model is prepared. The results found that the maximum stress is induced in top tube which is less than the yield strength of mild steel. So there is also scope to reduce the weight of the frame by considering the current stresses obtained.

M.A. Maleque and S. Dyuti published a paper on Material selection of Bicycle frame using Cost per unit property and Digital logic methods. In this paper they have selected the best material based in two methods, the initial screening of the material is done by ASHBY's chart. Multiple properties such as tensile strength, yield strength, young's modulus, toughness and density were considered for the optimum selection of the materials. The best material they found is kevlar fiber reinforced polymer (KFRP).

L. Castejón, A. Miravete, J. Ullod, E. Larrodé done a research on Composite monocoque frame for a mountain bicycle: Testing and calculation, which shows the way in which a monocoque frame of a mountain bicycle made of carbon fiber and Kevlar laminate, a poliurethane foam core and different metallic stiffeners were analyzed. The study was performed in two parts, namely, a first part in which the bicycle was tested considering several static and dynamic cases and a second part carried out by using the F.E.M., from which vibration frequencies and modes were obtained

III. PROCESS METHODOLOGY

For the present study, the strength comparison of composites (HT Graphite epoxy, S-Glass Epoxy) with Aluminum for both circular and elliptical cross-section of the frame member is carried in ANSYS Software.

Although the prominent cross sectional model for bicycles have been tubular, mainly hollow, our design method includes circular and elliptical cross-section. Adopting rounded contours instead of cornered edges was conceived and utilized due to the transverse effects it has on the applied stresses. Under an applied load, a frame with cornered edges would institute stress concentrations at the edges, lowering its ultimate strength and weakening the structure. Rounded perimeters help to disperse any applied load along the cross section eliminating any stress concentrations and stress raisers. This decision also incorporates the safety and comfort of the prospective rider. Organic, rounded edges will provide a higher level of assurance and amenity rather than an abrupt angle

IV. MATERIAL SELECTION

Beforeyoubegintoformatyourpaper,firstwriteandsavethecontentasaseparatetextfile.Keepyourtextandgraphicfilesseparateuntilaftert hetexthasbeenformattedandstyled.Donotusehardtabs,andlimituseofhardreturnstoonlyonereturnattheendofaparagraph. As per the material survey the best suited material is the aluminum alloy which is commonly used. Then composite materials like HT Graphite epoxy, S-Glass Epoxy are preferred due to its low density and compatible yield strength. These materials were chosen for designing frame and comparing its results. Thus this paper focuses on optimizing bicycle frame with different materials.

Material	Modules of Elasticity(GPa)	Ultimate Tensile Strength (MPa)	Yield Strength(MPa)	Density (kg/m^3)	Cost per kg in Rs
Aluminum Alloy 6061T6	68.9	310	276	2800	350
S glass Epoxy(composite)	90	3750	3450	2630	90
HT Graphite Epoxy (Composite)	221	3600	2000	1750	150

Table shows the Material Properties

V.Design Parameters of a Model:

The following are the parameters that are considered for the design of Bicycle frame.

General dimensions of bicycle:

parameters		
	Length(mm)	**Angle**
Length of the tube	**120**	-----
Length of the seat tube	**382**	-----
Length of the top tube	**500**	------
Head tube angle	-----	**77**
Seat tube angle	------	**77**
Seat stays	**440**	-----
Chain stays	**325**	------

Table shows the general dimensions of bicycle

General Dimensions for Hallow Circular Cross-section:

Dimensions of elliptical cross-section, Wall thickness will be 2 mm for both hollow circular and elliptical cross section

parameters	**Values**	
	Inner dia (mm)	**Outer dia (mm)**
Head tube	21	25
Seat tube	21	25
Top tube	21	25
Seat stay	12	16
Chain stay	12	16

Table shows the general dimensions of hallow circular cross-section

IV Designing of the Model:

Required CAD was developed using SOLIDWORKS modeling software. The cad geometry has basic requirement for Head tube, top tube, bottom tube, chain stays, seat stays, bottom bracket shell and the two triangles commonly says diamond frame. This is the model of the bicycle frame. A bicycle frame is the main component of a bicycle, onto which wheels and other components are fitted.

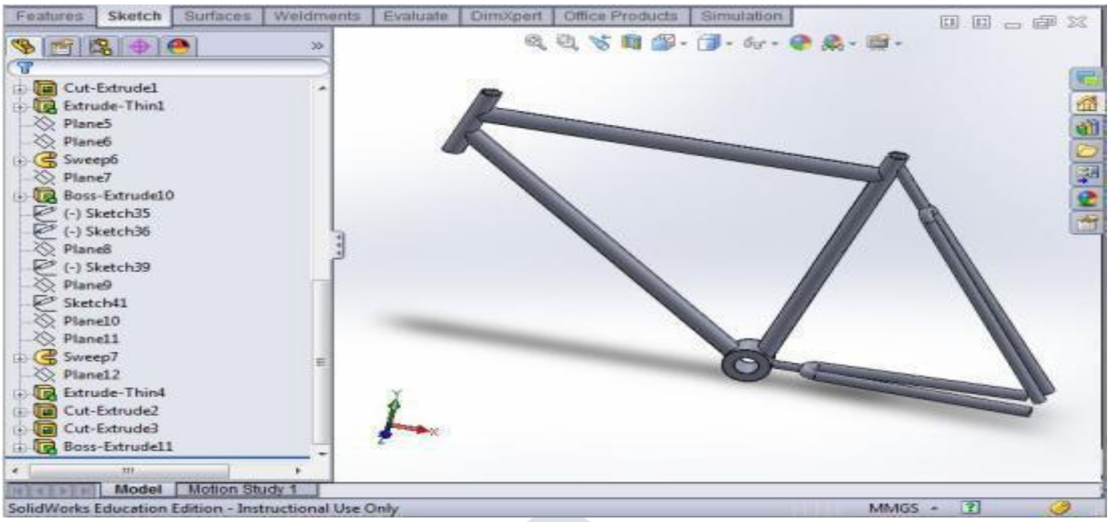
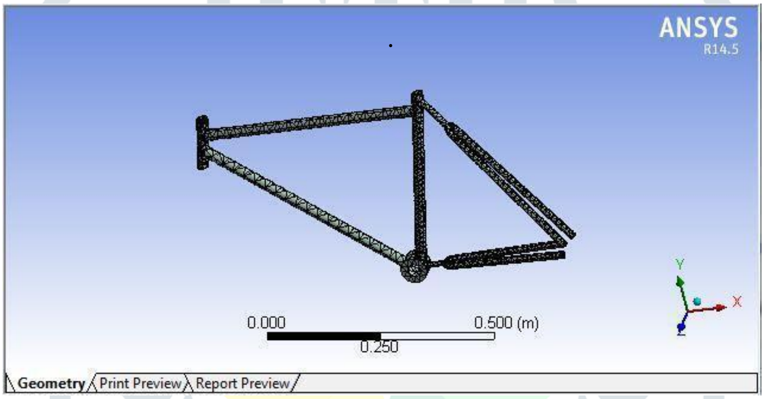


Figure shows the model with seat stays**(Circular Cross-section)**

VII .Meshed model of Bicycle Frame (Circular Cross-Section):



The figure shows circular cross section frame with fine mesh

7.1 Boundary conditions

The following figures shows how the fixed supports are provided and how the loading of 900N is applied by static start up method on the bicycle frame

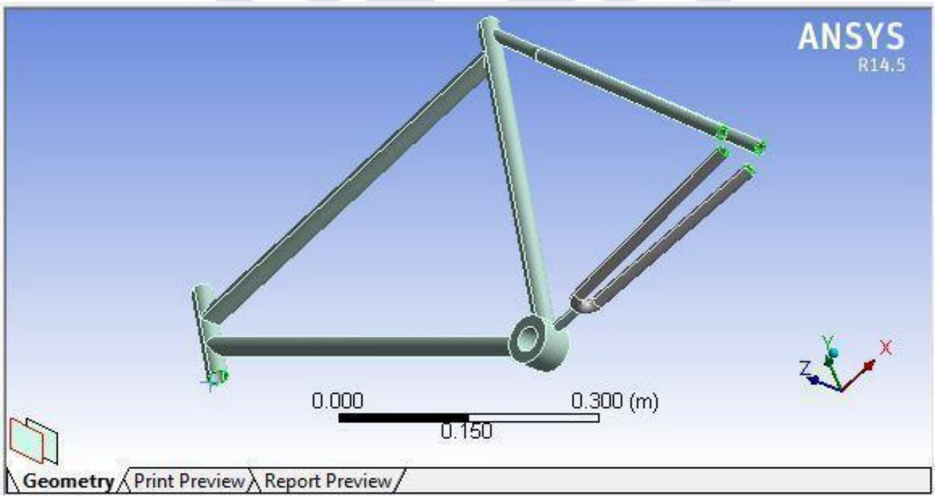


Figure shows the Fixed supports

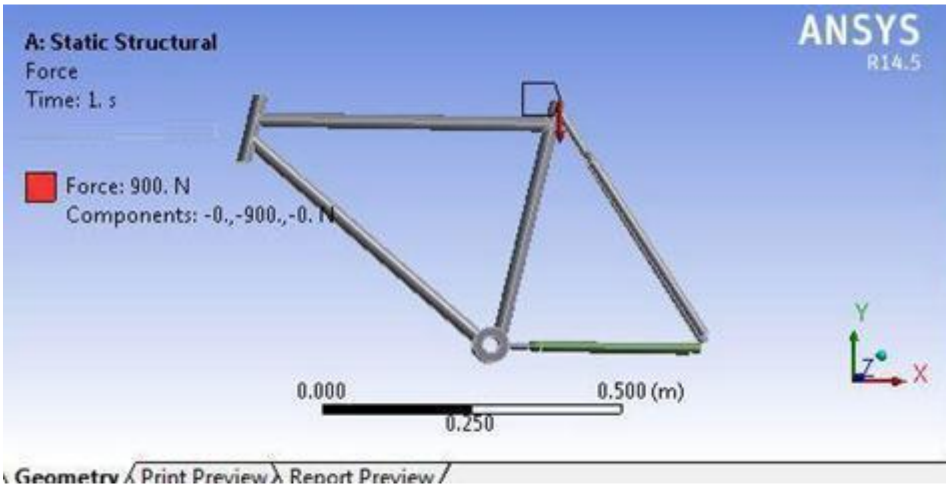


Figure Loading on frame

7.2 Circular Cross-Section:

Maximum Von-Mises stress for Aluminum 6061-T6 is 1.5896e7 Pa. Maximum Von-Mises stress for HT Graphite Epoxy is 1.6251e7 Pa. Maximum Von-Mises stress for S-Glass Epoxy is 1.6332e7 Pa

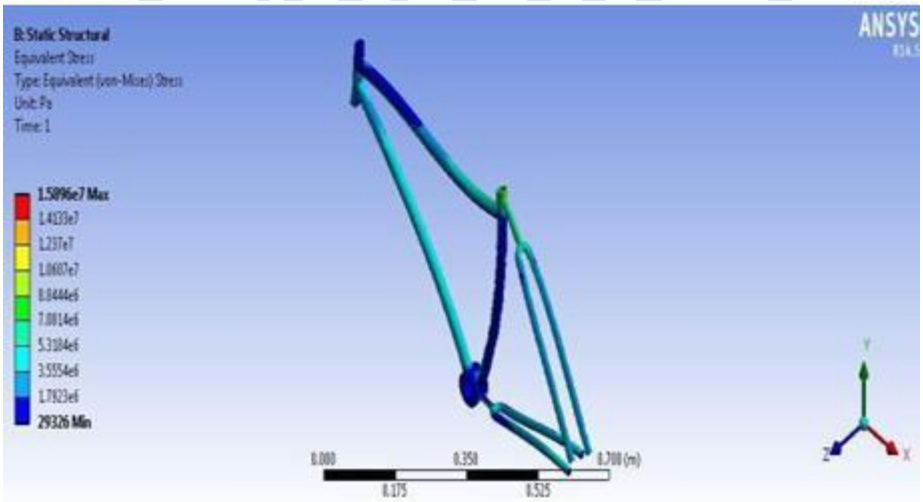


Figure stress (Aluminum 6061-T6)

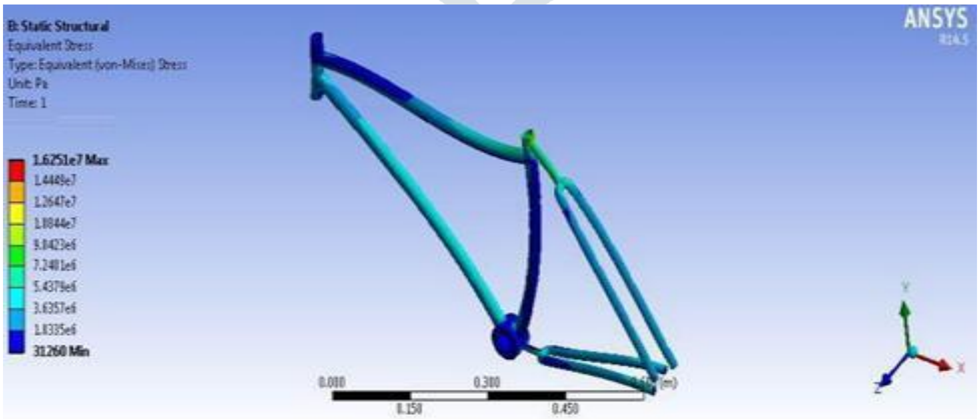


Figure Stress (HT Graphite Epoxy)

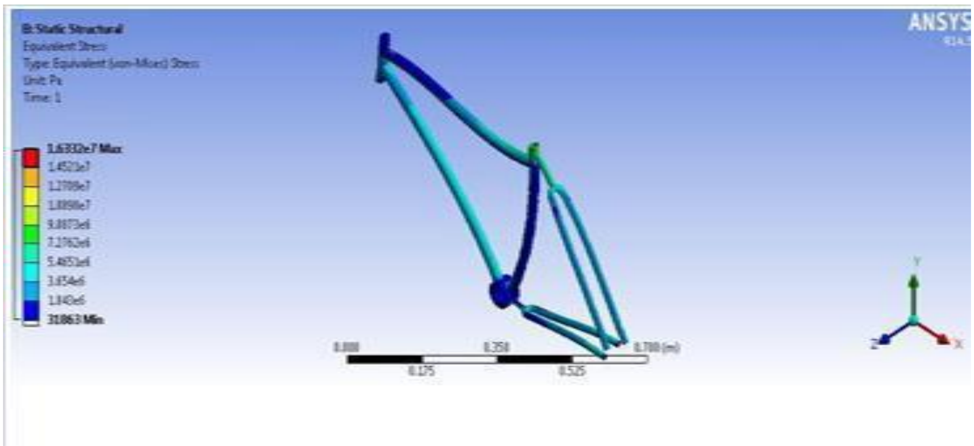


Figure Stress (S-Glass Epoxy).

7.3 Elliptical Cross-Section:

Maximum Von-Mises stress for Aluminum 6061-T6 is 3.8132e7 Pa. Maximum Von-Mises stress for HT Graphite Epoxy is 3.8362e7 Pa. Maximum Von-Mises stress for S-Glass Epoxy is 3.8443e7 Pa

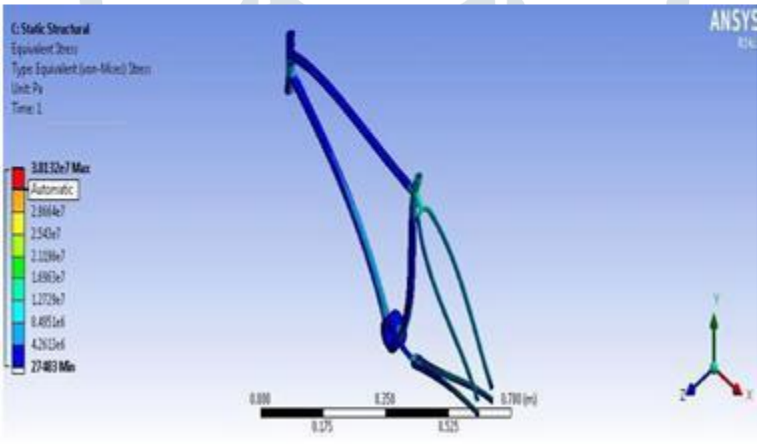


Figure shows the Stress (Aluminum 6061-T6)

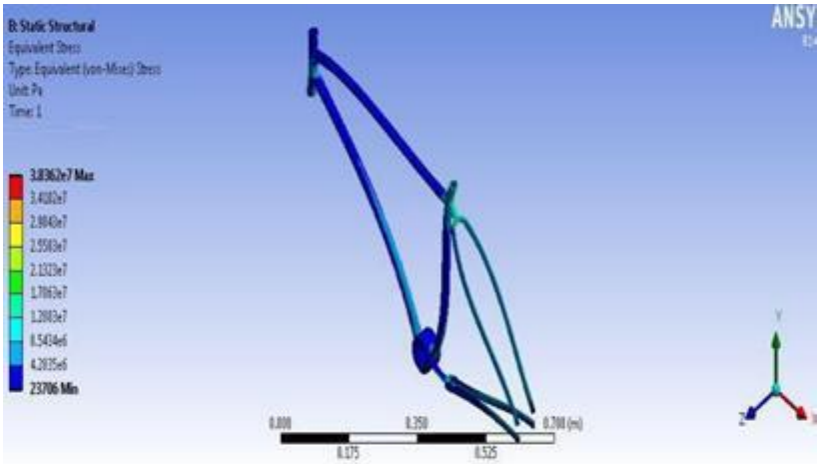
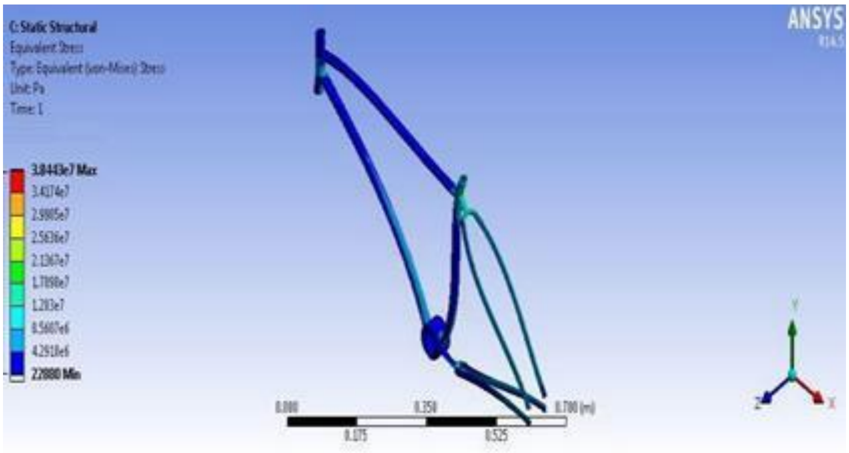


Figure shows Stress (HT Graphite Epoxy).



Figures shows the stress (S-Glass Epoxy)

7.4 Circular Cross-Section:

Maximum Von-Mises strain for Aluminum 6061-T6 is 0.00023094 Pa.Maximum Von-Mises strain for HT Graphite Epoxy is 7.3595e-5 Pa.Maximum Von-Mises strain for S-Glass Epoxy is 0.00018162 Pa.

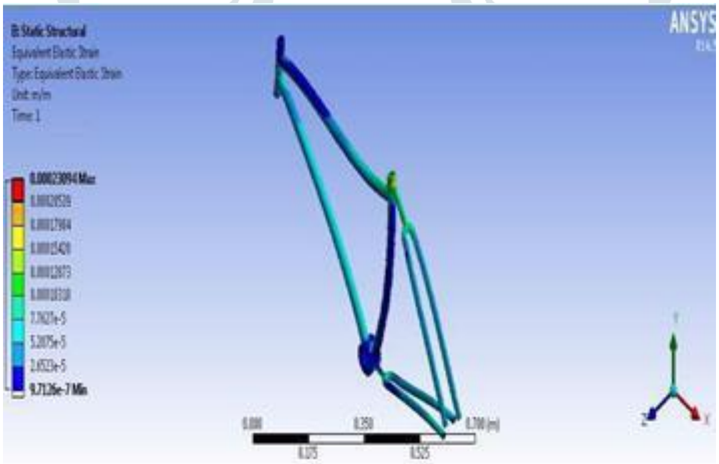


Figure Strain (Aluminium 6061-T6)

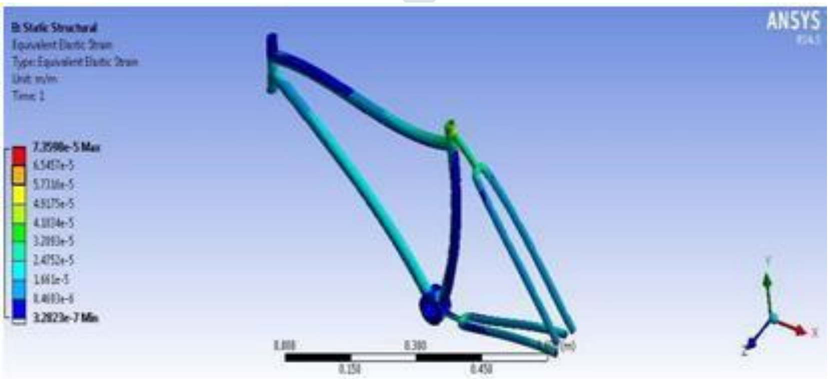


Figure Strain (HT Graphite Epoxy).

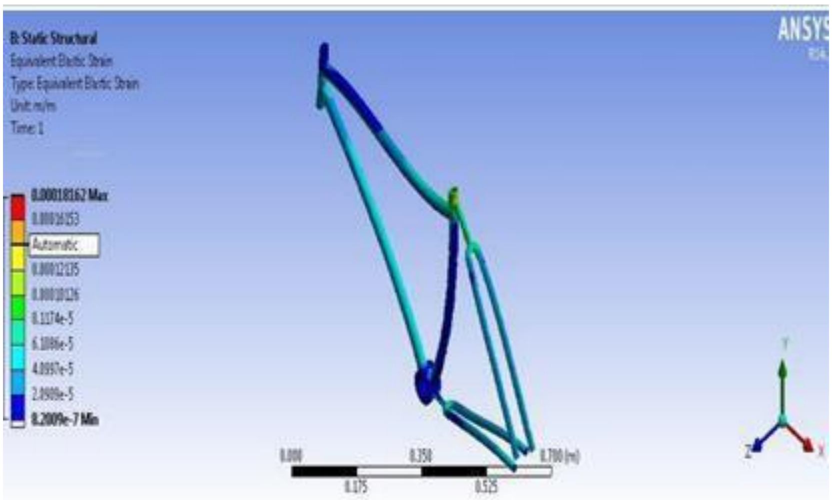


Figure Strain (S-Glass Epoxy).

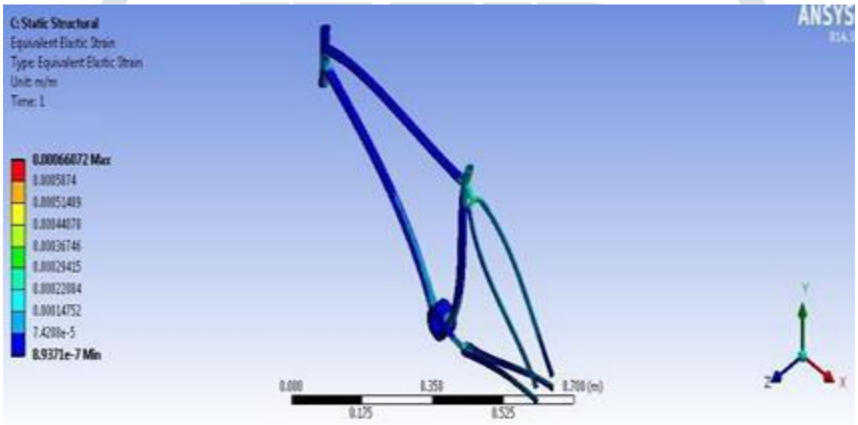


Figure strain(Aluminium 6061-T6)

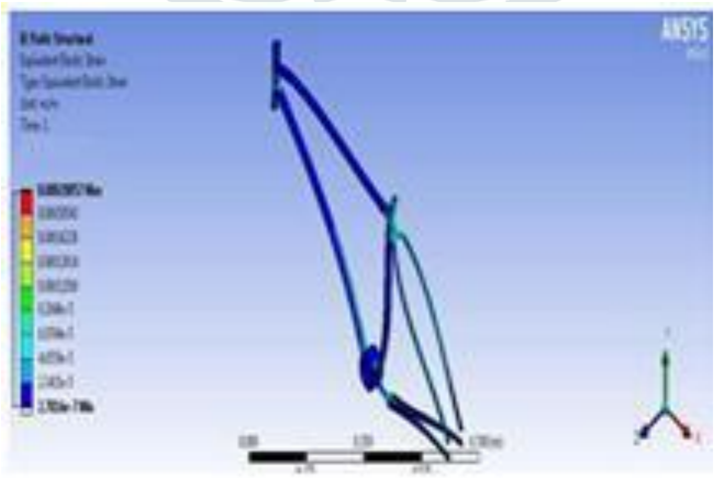


Figure Strain (HT Graphite Epoxy)

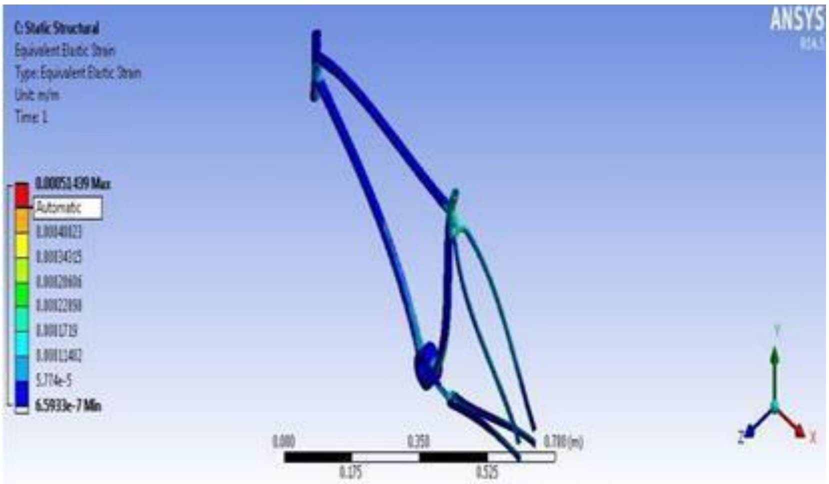


Figure Strain (S-Glass Epoxy)

VIII. Displacement Analysis:

After the pre-processing stage of analysis in Ansys R14.5 for static structural analysis was completed (geometry definition, material definition, mesh generation, loading and defining constraints), then during the solving of our problem there will be a formation of element matrix, Overall matrix triangulation and Wave front in the frame member to obtain total deformation and the calculations takes place, then the following overall deformation in the frame members are obtained for different material in both circular cross-section and elliptical cross-section frame member.

8.1Circular Cross-Section:

Maximum displacement for Aluminium 6061-T6 is 9.1385e-5 mm.Maximum displacement for HT Graphite Epoxy is 2.8539e-5 mm.Maximum displacement for S-Glass Epoxy is 6.2309e-5 mm

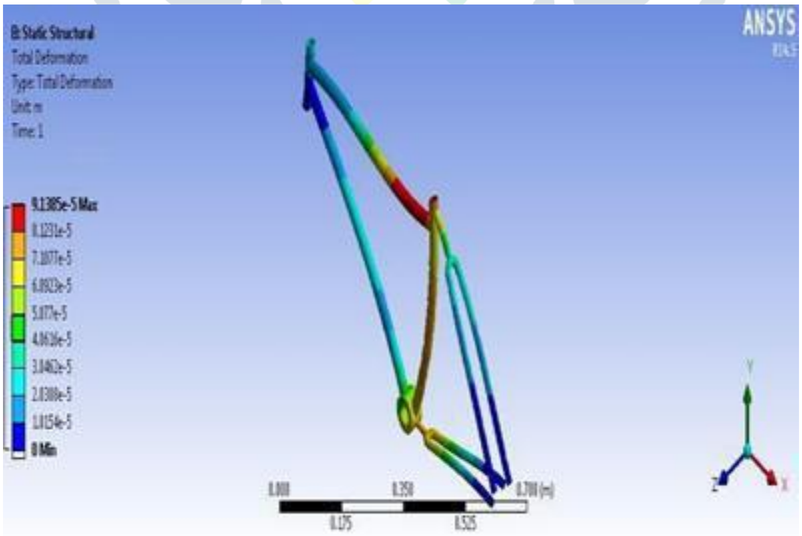


Figure Deformation(Aluminium 6061-T6)

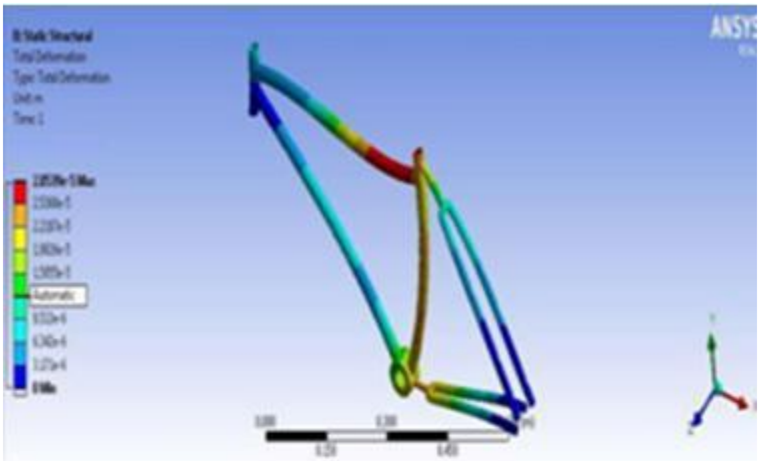


Figure deformation (HT Graphite Epoxy)

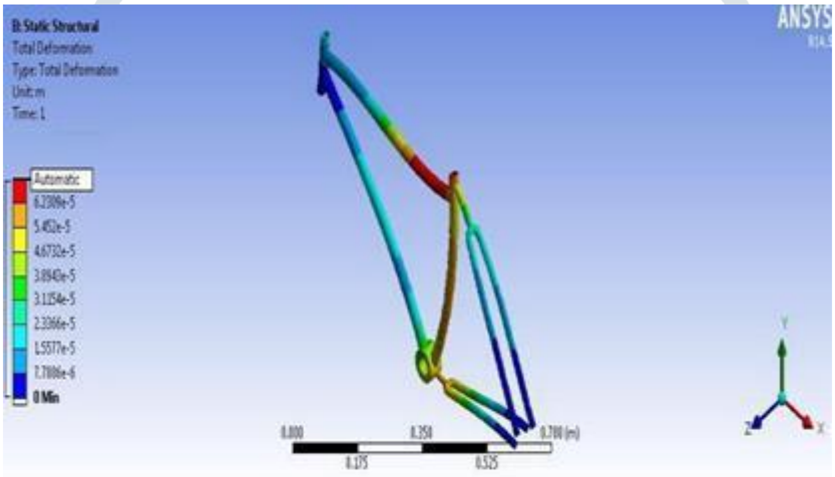


Figure deformation (S-Glass Epoxy)

8.2 Elliptical Cross-Section:

Maximum displacement for Aluminum 6061-T6 is 0.00015066 mm. Maximum displacement for HT Graphite Epoxy is4.7279e-5 mm. Maximum displacement for S-Glass Epoxy is 0.0001033 mm.

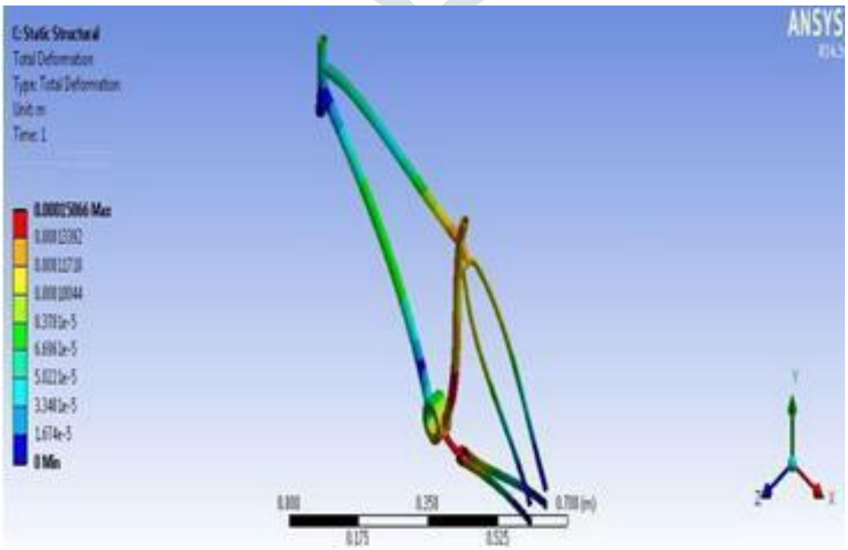


Figure deformation (Aluminium 6061-T6)

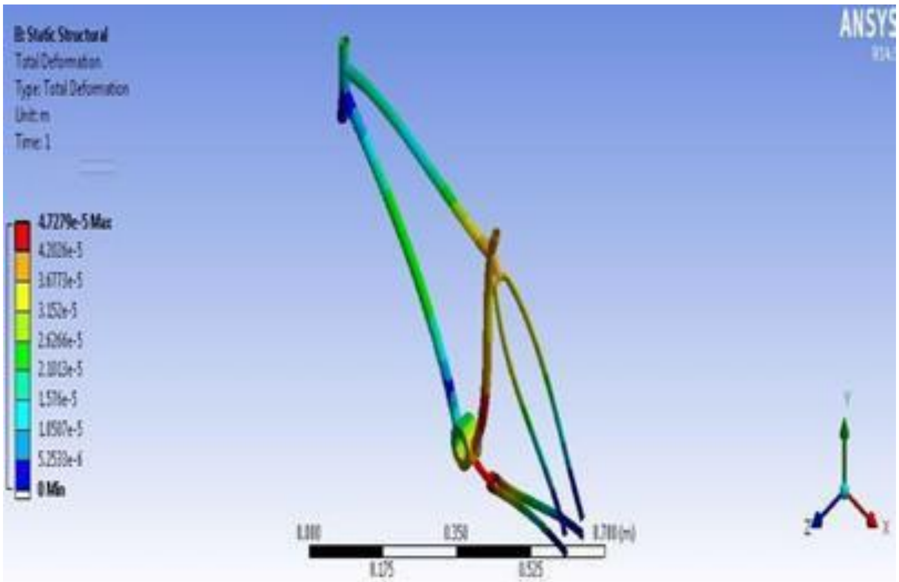


Figure deformation (HT Graphite Epoxy)

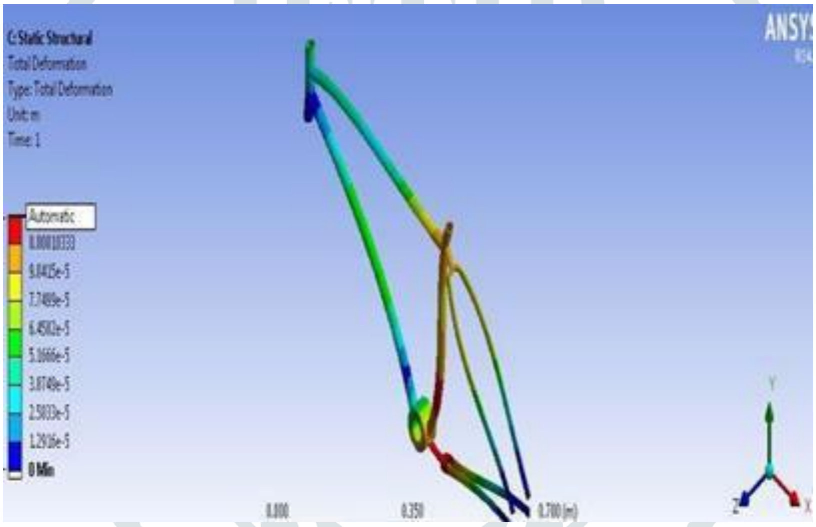


Figure deformation (S-Glass Epoxy).

IX .DISCUSSION

Comparison of Aluminium Alloy6061-T6 with HT Graphite epoxy and S-Glass Epoxy (Circular cross-section):

Comparison of stress, strain and deformation for Circular cross-section frame member

S.No	Particulars		Circular cross sections		
	Result		**Aluminium Alloy 6061-T6**	**HT Graphite Epoxy**	**S-Glass Epoxy**
1	VON-MISES STRESS(Pa)	Max	1.5896e7	1.6251e7	1.6332e7
2	VON-MISES STRAIN(Pa)	Max	0.00023094	7.3595e-5	0.00018162
3	TOTAL DEFORMATION(mm)	Max	6.2309e-5	2.8539e-5	9.1385e-5

Table show Comparison of stress, strain and deformation for Circular cross-section frame member

Comparison of Aluminium Alloy6061-T6 with HT Graphite epoxyand S-Glass Epoxy (Elliptical cross-section):

Comparison of stress, strain and deformation for Elliptical cross-section frame member

S.No	Particulars		Eliptical cross sections		
	Result		Aluminium Alloy 6061-T6	HT Graphite Epoxy	S-Glass Epoxy
1	VON-MISES STRESS(Pa)	Max	3.8132e7	3.8362e7	3.8443e7
2	VON-MISES STRAIN(Pa)	Max	0.00020857	0.00066072	0.00051439
3	TOTAL DEFORMATION(mm)	Max	0.00015066	4.7279e-5	0.0001033

Table shows the Comparison of stress, strain and deformation for Elliptical cross-section frame member

X .CONCLUSION

From the Results and Discussion which are tabulated in the above table 5.1 and 5.2, composites (HT Graphite epoxy and S-Glass Epoxy) can be used as Bicycle frame material because of better results (stress, strain & displacement) when compared with Aluminum Alloy6061-T6.

- The maximum Von-Mises stress for circular cross-section is 1.6332e7 Pa.
- The maximum Von-Mises stress for elliptical cross-section is 3.8443e7 Pa
- The maximum Von-Mises strain for circular cross-section is 7.3595e-5.
- The maximum Von-Mises strain for elliptical cross-section is 0.00066072.
- The Total Deformation obtained in circular cross-section is 9.1385e-5mm.
- The Total Deformation obtained in elliptical cross-section is 4.7279e-5 mm.

Therefore, for the bicycle frame the Circular cross section is more preferable than Elliptical cross-section because of high strength withstanding ability. Then in the two composite materials (HT Graphite epoxy and S-Glass Epoxy) S-Glass Epoxy can be preferred when compared to HT Graphite Epoxy because of less cost and reasonably high strength than HT Graphite Epoxy.

REFERENCES

1 Mr M V pazare Prof S D Khamankar "STRESS ANALYSIS OF BICYCLE FRAME "International Journal of Engineering Science and Technology (IJEST).

2. Sagar Pardeshi, Pankaj Desle"DESIGN ANDDEVELOPMENT OF EFFECTIVE LOWWEIGHT RACING BICYCLE FRAME"International Journal of Innovative Research in Science Engineering and Technology Vol. 3, Issue 12December 2014 ISSN: 2319-8753

3. M. A.Maleque and S.Dyuti "MATERIALSSELECTION OF A BICYCLEFRAME USINGCOST PER UNIT PROPERTY AND DIGITAL LOGICMETHODS" International Journal of Mechanical and Materials Engineering(IJMME), Vol. 5 (2010), No. 1, 95-100.

4. L. Castejón, A. Miravete, J. Ullod, E. Larrodé"COMPOSITE MONOCOQUE FRAME FORA MOUNTAIN BICYCLE: TESTING AND CALCULATION" Applied Composite Materials1994, Volume 1, Issue 3, pp 247-258

5. Fabian Fuerle , Johann Sienz "DECOMPOSEDSURROGATE BASED OPTIMIZATION OFCARBON-FIBERBICYCLEFRAMES USINGOPTIMUM LATINHYPERCUBESFORCONSTRAINED DESIGN SPACES".

6. Forrest Dwyer Adrian Shaw, RichardTombarelli presented the thesis on "MATERIALAND DESIGN OPTIMIZATION FOR ANALUMINIUM BIKE FRAME**".**

7. Derek Covill, Steven Begg, Eddy Elton, Mark Milne, Richard Morris, Tim Katz"PARAMETRICFINITEELEMENTANALYSISOFBICYCLEFRAMEG EOMETRIES", The 2014 conference of the International Sports Engineering Association, Procedia Engineering 72 (2014) 441 – 446

8. D.S.DeLorenzo,M.L.Hull"QUANTIFICATIONOFSTRUCTURALLOADIN G DURING OFF-ROAD CYCLING",

9. Thomas Jin-Chee Liu, Huang-Chieh Wu, "FiberDIRECTION AND STACKINGSEQUENCEDESIGN FOR BICYCLE FRAME MADE OFCARBON/EPOXY COMPOSITE LAMINATE",23 October2009 www.elsevier.com.

10. D. Arola, P. G. Rainhall, M .G. Jenkins, S.C. Iverson, "AN EXPERIMENTAL ANALYSISOF HYBRID BICYCLE FRAME", May-June 1999, Experimental techniques

11. David Lopez, Jovan May field, & Pierre MarcParas, "STRESS ANALYSIS OF BICYCLE", 9[t]December 2010, ME3213 Project.

12. 12.ThomasJin-CheeLiu,Huang-ChiehWu"FIBER DIRECTION AND STACKING SEDUIENCE.DESIGN FOR BICYCLE FRAME MADE OF BONE EPOXY COMPOSITE LAMINITE" Materials and Design 31 (2010) 1971–1980

13. Bharati A. Tayade , T.R.Deshmukh, "A STUDYON STRUCTURAL HEALTH OF BICYCLEFRAME USING FINITE ELEMENT ANALYSIS", International Journal of Innovative and Emerging Research in Engineering Volume 2, Issue 4,2015

14. DerekCovilla,StevenBegga,Eddy Eltona,Mark Milnea, Richard Morrisa, Tim. Katza,"PARAMETRICFINITEELEMENTANALYSIS OF BICYCLE FRAME GEOMETRIES", The 2014 conference of theInternational Sports Engineering Association Procedia Engineering 72 (2014) 441 – 446

15. Lessard, L., Nemes, J., Lizotte, P. 1995."UTILIZATION OF FEA IN THE DESIGN OF COMPOSITE BICYCLE". Composites, 26(1),72-74